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August 1988
NSRP 0298

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1988 Ship Production Symposium

Paper No. 9B: Affordable Technologies for Small Shipyards

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **AUG 1988**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **The National Shipbuilding Research Program: 1988 Ship Production Symposium Paper No. 9B: Affordable Technologies for Small Shipyards**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**15**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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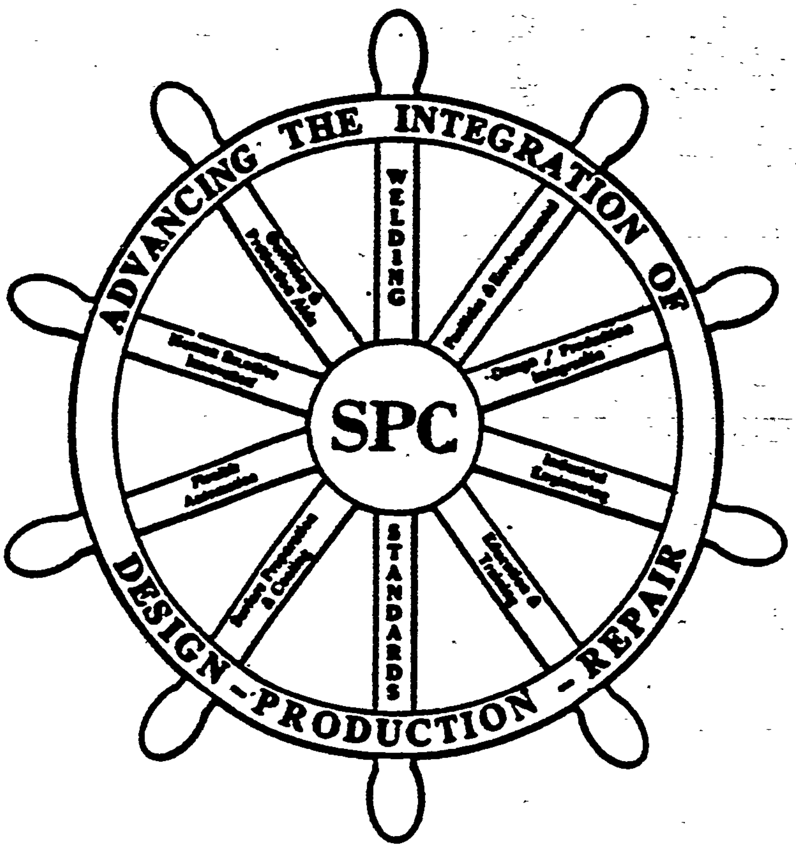
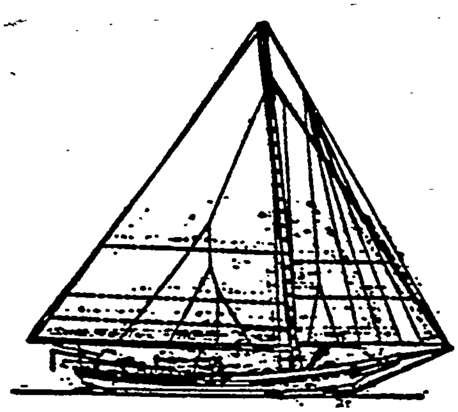


August 24-26, 1988
Edgewater Inn
Seattle, Washington



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601 Pavonia Avenue, Jersey City, NJ 07306
Paper presented at the NSRP 1988 ship Production symposium
Edge water inn Seattle Washington August 24-26. 1988

Affordable Technologies for Small Shipyards No. 9B

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ABSTRACT

This paper attempts to recast some large shipyard production technologies in light of the needs of small yards. The importance of small shipyards to the nation's marine economy is addressed and three methods are offered as affordable ways of increasing yard productivity. These ace operations management. numerical lofting, and zone outfitting. The paper concludes with a call for in- &eased attention to the problems of small yards.

INTRODUCTION

As others have before, we will begin by taking a brief look at history in order to set the scene for this discussion. The history of modern shipbuilding has been well covered by many sources such as Ref. (1). However, past discussions have been directed et large yards building commercial or naval vessels. Lets look briefly et smaller yards.

Throughout America's history, the principal requirement for a shipyard has been a site along a river or harbor front and some skilled labor. For example the Story yard, set on the banks of the Essex river in Massachusetts, consisted of a sloping open area for the ways and some small outbuildings. This yard successfully built many Grand Banks schooners using the proven method laying a keel, Installing sawn frames, and then planking. With the hull finished, work shifted to installing the deck structure and then final interior outfitting. Launching was a grand occassion for the yard workers and their families.

Bring the date up to 1988, substitute steel and welding for wood and nails, and you have a typical smell yard (Fig. 1). The vessels have changed but the basic proceedure of building them has not. Quite a contrast with large yard where more productive methods have been brought into play.

The current shipbuilding industry is a troubled one. Large yards nationwide are seeing a dearth of new construction in commercial vessels and the result has been the closing of yards such as General Dynamics in quincy, Massachusetts, and Lockheed in Seattle, Washington. The slump that occurred in the mid-80's also affected many small yards since several segments of the workboat market were depressed concurrently. We are seeing some recovery in the offshore oil industry and fishing vessel work is strong in the Northwest. What does this mean for the marine industry? Small yards form a significant portion of U.S. shipbuilding and repair activity. Their pool of trained labor and consumption of marine equipment is vital to large vessel activity, both commercial end naval. If small yards can adopt improved shipbuilding methods then the entire marine community will benefit.

Before proceeding further, let's define some terms:

Small Yard

A small business can qualify for special federal considerations if it employs under 500 people. For the purpose of this paper a small yard is one that has less then 250 employees and has gross sales of under $20M per year.

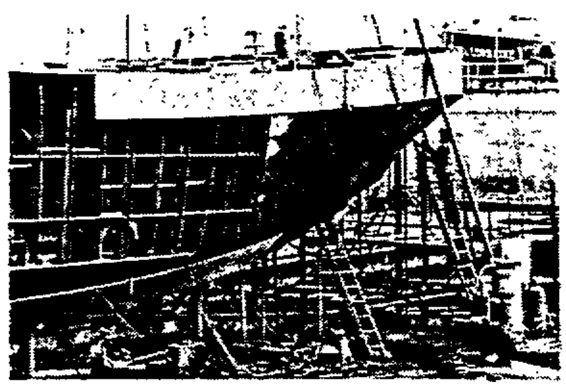

Figure 1
Construction of a Tractor Tug

Technology

Webster's Dictionary defines technology as "The Science or study Of the practical or industrial arts". we will narrow that vista to focus on new methods, not materials or equipment.

New construction

For the size of yards being discussed the vessel types usually enCOUntered consist of workboats, passenger vessels, barges and fishing vessels, all of simple construction and non-exotic materials. Three hundred feet length overall is a practical upper bound.

Repair

small yards can often handle a wide range of vessel types for repair being limited typically by drydock size and/or available pier length. Repairs consist of annual maintenance, conversions, or damage repairs. Repair work is typically differentiated from new construction by less steel work and adapting to existing geometry and equipment.

In this paper we propose to present several examples of modern technology that can improve small yard productivity at an affordable cost. The ideas discussed below are familiar to readers of ship production journals so we ask for patience as we direct our remarks to small yard operators. We do not claim that these ideas are the only ones that small yards can implement. to improve their productivity. on the contrary, the Authors hope that this paper will engender a discussion on how small yards can work smarter and help the marine industry.

To be applicable to small yards any new technology must be flexible in its implementation and modest in cost. A small firm cannot afford to throw all procedures into the dustbin of history so implementation should be piecemeal. The methods involved in modern new ship production require extensive planning, a traditional weakness of small yards, so their use will involve some pains as the yards change methods but those pains need not be crippling. We feel that the following ideas are a place for small shipyards to start.

OPERATIONS MANAGEMENT

We will not presume to Suggest that every small operation needs a management overhaul, but due to the competitive nature of the marine industry today we hope that all yards will actively seek a competitive advantage. The idea of a competitive advantage will be the cornerstone of this discussion.

To maintain competitive pricing each yard must be able to collect and analyze production cost data. This information is then translated into future cost estimates. Large yards have departments of estimators, planners, and accountants collecting and reviewing project data. Estimators provide a baseline for project cost control. planners schedule engineering, purchasing, and production to optimize available labor, materials, and facilities. Accountants compile the project Costs which provide the information for project evaluation. small yards usually have only a limited estimating Staff which results in a broad brush approach to estimating. General factors and ratios which have proven competitive are used to bid jobs. This approach Carries a low degree of confidence when the time comes to trim prices. The problem Of cost control arises after the project has begun with attention focusing only on completion with little or no control over resource allocation or material costs. Below we will discuss creating a standard production framework, project scheduling, and methods of project evaluation in order to gain greater control of project management.

standard production Framework

A standard production framework defines common blocks within departments or crafts. Each yard has a unique framework based on historical construction methods, breaking vessel construction into manageable sections. A simple framework would consist of' the bow, midbody, stern, and superstructure. These four areas would then form the subtotals of a project cost estimate, the main blocks for planning, and the categories for cost control. Even though these areas differ from to vessel, the required work remains relatively common. For example, a bow shape may change but the process of working the complex shapes is common to most self propelled vessels. This approach may appear much too broad to provide any significant information but experience proves otherwise. A figure for feet of weld per hour can not be calculated using this method, but steelwork labor hours per pound can be produced. AS information is collected for each block the blocks can be broken into smaller assemblies as further definition is encouraged by top management. Once again, the goal of the framework is to provide common construction blocks for production evaluation and estimating future job costs.

P r o j e c t

Project scheduling is accomplished using various methods. The most common scheduling tool has been the Gantt or

bar chart. The format is simple and the information is relatively easy to understand. Until the late 1950's this was the main tool of the project manager, but as projects became more complex the ability to determine interdependencies between activities became a necessity. Interdependencies are the order in which tasks must be performed, for example, completing the welding in areas before they are painted. Understanding the need to define interdependencies led to the realization that scheduling should be a dynamic process. This may be the greatest hurdle to overcome in understanding the benefits of project scheduling. A realistic schedule can not be compiled at the start of a project with the intent that nothing will change. This dooms the schedule to failure.

Two methods were developed to assist in managing these dynamic relationships: project evaluation and review technique (PERT) and the critical path method (CPM). The critical path method is used most often in construction where the tasks can be defined with a fair degree of accuracy. PERT was developed for use in designing the polaris submarine weapon system, where many task durations were highly speculative, lacking prior estimating data. Although the two methods were developed independently, they share many of the same principles. The major difference is that PERT uses probability analysis to help determine task durations and the confidence level for timely project completion. By developing a standard framework to use as a template when estimating job costs and planning pre-project strategies, the information required to create a logical network will be available without starting over with each project. CPM is used to create a logical link between the tasks and milestones required to complete the project. Tasks are defined as items of work that require a" estimated duration of time to complete, where milestones ate major events which are a result of the completion of a task or a group of tasks. The critical path is determined by the sequence of tasks which have the longest aggregate duration as shown in Fig. 2. By joining those tasks into a network the impact of a delay in the completion of any task can be observed while time exists to plan alternative action, such as double shifts, extra personnel, or shipping needed materials by air.

The dynamic nature of scheduling has traditionally required large computing capacity either through large numbers of people or expensive computer equipment to calculate the impacts of progress on the schedule. Mathematical equations are used to produce the float time and optimum completion dates for the schedule. With the increasing power of microcomputers, at a cost that even small yards can afford, the potential for effective scheduling is finally available to small yards. Several software packages exist that can handle project scheduling if the project steps are completely defined. Computer magazines can be a good source of infor-

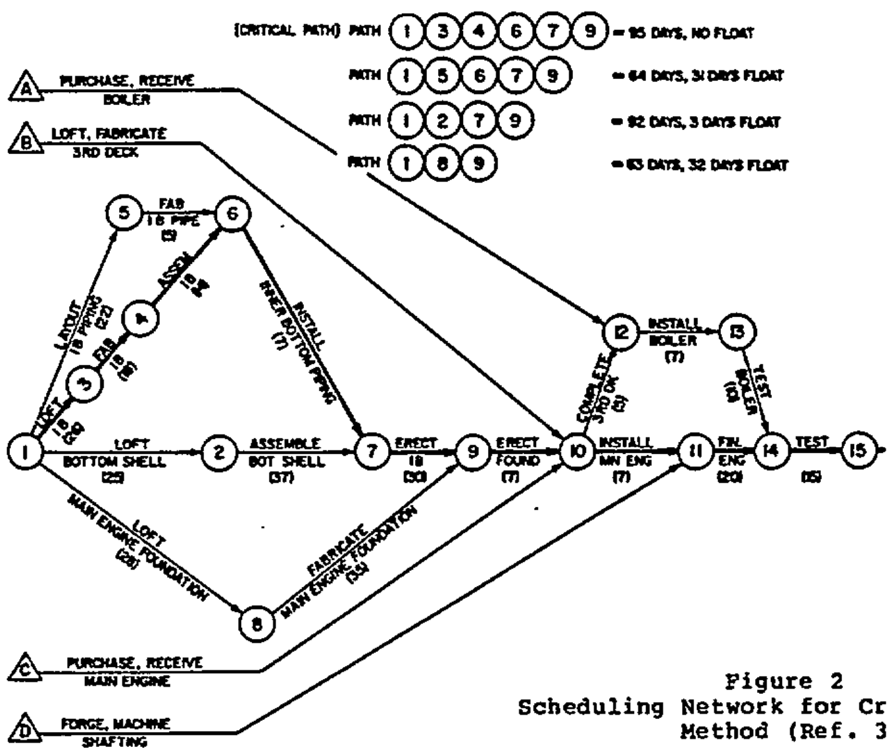

Figure 2
Scheduling Network for Critical Path Method (Ref. 3)

mation an software choices (Ref. 2).

Regardless of whether a computer is used, the key to effective scheduling is understanding how to define realistic project tasks with durations that will utilize the available labor most efficiently and recognizing the task interdependencies. A common question is: If we think out the project completely, why bother with a schedule? Such a question depicts the lack of understanding of interdependencies between departments. activities, material flows and other forces that are too complex to remain static over the duration of a project.

Material flows are often overlooked as a restraint on production. Manufacturing industries have out paced ship construction in their recognition of material flow problems. Materials must be available to the workers when needed. This requires material requirements to be defined long enough in advance to allow purchasing to arrange for delivery without paying a premium. By including purchasing of major materials and equipment in the schedule, fewer hours will be spent waiting for delivery.

<u>Project Evaluation Methods</u>

Project evaluation is most often done by subtracting the total costs at the end of of project from the contract price and hoping the resulting difference is a profit and not a loss. Creating a framework, as we discussed earlier, to provide a baseline for controlling project costs is a necessity to guide project management decisions during the course of job. To effectively monitor costs and maximize profits a method of progress analysis must be implemented. Without a framework of comparative estimated or historical costs and an effective scheduling procedure, defining standards for project evaluation becomes difficult if not impossible. To ensure the ability to gauge the project status, a baseline must be developed to compare estimated costs to actual costs. This is the only way to determine cost trends while action can still be taken to alter poor progress. Once again, the advancement of microcomputer technology offers a cost effective way to manage the cost control data. A serious problem in creating a computerized cost control system is that most software dictates that a yard follow certain standard accounting principles or only addresses basic bookkeeping functions. This may help with payroll but it will not establish a useful database for future bidding and project evaluation. custom software should be considered especially by a small yard that is concerned about maintaining their procedures and will not benefit by adhering to a generic accounting package. Modern programming environments have taken some of the horror out of setting up a custom control system. The initial cost of custom software may be slightly more but the training time and general confusion caused by new systems will be far less. These systems should be set up to support, not to inhibit, effective production.

Implementation of a standard framework, scheduling methods, and project cost controls are difficult for most companies due to the general lack of operational goals and methods.. Large yards who deal mainly with the U.S. Government are required to adhere to certain procedures. Even though this produces mixed results it does Set some guidelines to aid in establishing Systems, The commercial customers with whom most Small yards participate care mostly about price. Effective scheduling and estimating offer a way to reduce costs by providing continuous feedback on progress and problems.

NUMERICAL L0FTING AND NC CUTTING

Surely one of the most critical aspects of vessel construction is the determination of the bull shape in full scale and the lofting of individual pieces for construction. Ref. 3 defines lofting as: "The process of developing the Size and Shape of components of the ship from the designed lines; traditionally, making templates using full scale lines laid down on the floor of the mold loft; today, largely performed at small scale using photographic or computer methods.* The fairness of the hull form and the accuracy of the cut parts have a direct impact on the time required for construction. Any means then to expedite this process or, more importantly, to increase the accuracy, results in decreased construction costs.

The advantages of traditional methods of lofting are few while the disvantages are numerous. The primary reasons for continuing to practice full scale lofting are:

- Small capital investment required to layout a hull full scale.
- Lack of knowledge of more modern methods.
- Reluctance to deviate from proven methods.

The disadvantages of full scale lofting that are offset by more modern methods include:

- Large amount of space required to develop a hull form in full scale (Fig. 3).
- Large amount of space required to store part templates after

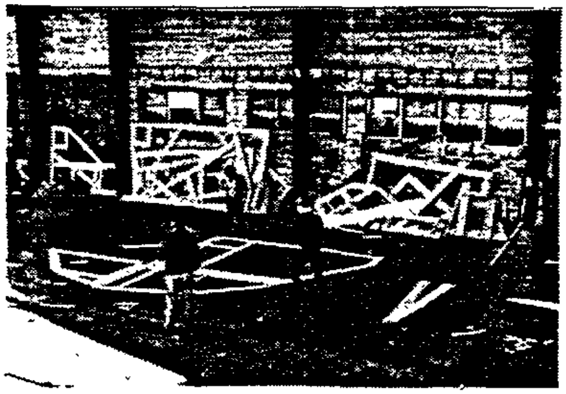

Figure 3
Traditional Layout of Tugboat Bulkhead

construction of first hull.
- Time necessary to effect changes to hull form or parts once lines are down and vessel is lofted.
- Eradication of old lines upon lofting of a new vessel.

In the late '50's and early '60's, various shipyards began to experiment with numerically controlled (NC) burning machines to Cut steel plate. These machines had the potential to increase the accuracy of cut steel parts and decrease the manhours required to cut those parts. In those early times, coordinates defining the shape of a part were entered at the keyboard by hand utilizing offsets obtained from the loft floor. Currently, prices of NC burning equipment have put them within the reach of even small shipyards (Fig. 4).

With the advent of the NC burner came the ability to use scaled down versions of the hull lines. No longer was it necessary to use full scale lines to obtain part geometry and l/10th scale lofting using manual methods became popular. It was then a simple matter to mechanically measure and record coordinates from 1/10th scale part templates and eliminate the keyboard entry of coordinates and NC code.

Computer aided lofting. was an obvious outcome of automation of manufacturing systems. As numerically controlled manufacturing systems were developing, computers were also developing and it was only a matter of time until the two were linked, eliminating the traditional mold loft floor as the source of all vessel geometry information. Computer lofting has many advantages over full scale lofting. Storage of the hull form and *part* templates is a major consideration. No longer is it necessary to have large space allocations for template storage. Computer generated hull lines are also easier to modify to meet new requirements, or to effect hydrodynamic changes after test-

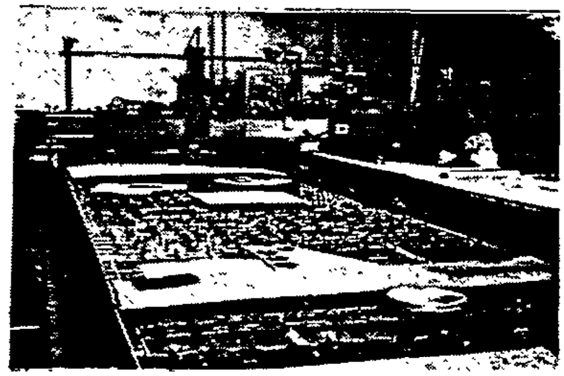

Figure 4
Typical Small Yard Burning Table
Courtesy MARCO

ing. There is no longer a necessity to remove an existing loft floor. The magnetic data base is easy to store and to duplicate, thereby reducing insurance risks.

Computer lofting can be broken into two major categories:

<u>Hull definition and fairing</u>

There are a number of hull definition programs currently available, both in the public domain and through private parties.

* Sophisticated systems

  They are less labor intensive, demanding less input from the operator. They have the ability to automatically generate structure and shapes. They typically support design and analysis packages such as vessel hydrostatics calculations.

* Public Domain Software

  The software available as public domain software can be a very cost effective means to do computer lofting. Typically, the programs demand powerful computer systems to run, thus requiring time sharing computer services or hiring a consultant. These programs can be very time consuming and labor intensive to use if compliance with an existing bull form is a necessity. Many of these programs also require manual integration with other design and analysis programs.

* Inexpensive fairing programs

  These can be an excellent value if used to generate a hull from the preliminary design stage (Pig. 5). They are usually limited as to the

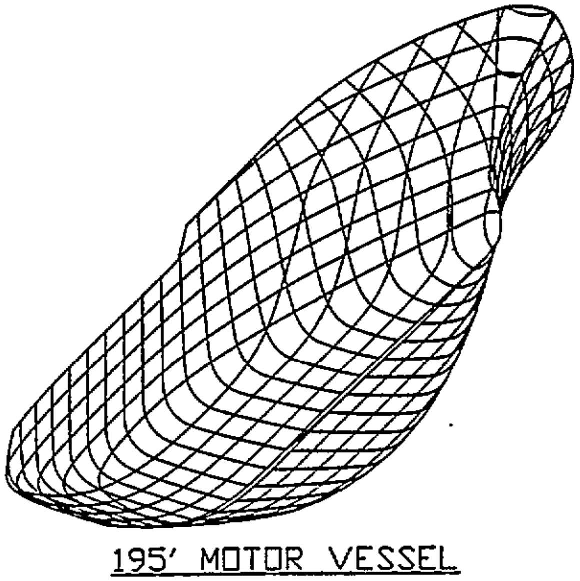

Figure 5
Micro-COmputer Lines Generation

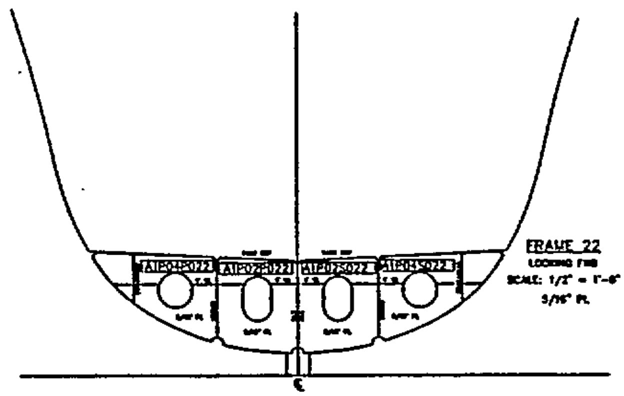

Figure 6
Computer Lofted Frame

complexity of hull forms that they can handle and therefore have limited application. They also require manual integration with other programs.

The proliferation of programs for micro-computers means that there is now software for generating developable surfaces and creation of foil shapes using standard NACA sections. True three dimensional shape manipulation is expected in the near future.

Part definition

Parts definition involves extracting shape information from the computer hull shape to define decks. frames, bulkheads, etc. These structural areas are then further broken down into individual parts. Where necessary the parts are developed into flat shapes and detailed with lightening holes, construction reference lines and piece numbers (Fig. 6). Once the part geometry is completely defined the manufacturing considerations of tool path and kerf can be added, resulting in a piece ready for nesting and NC cutting;

An advantage t0 parts definition by computer is the ability to check the accuracy of the parts and completeness Of the structure before parts are actually cut. Because the pieces are assembled first on the computer, they can be checked for fit before they become parts. The greater accuracy leads to easier construction with less rework. The overall result is a less expensive, higher quality product.

The computer also gives the ability to track weight of materialS, allowing analysis of module weights, increasing estimating accuracy, and giving greater control of costs.

More planning is required with computer lofting since each piece must be determined in advance. Thought must be give" to a numbering system to identify parts as they arrive from the steel yard and their storage must be organized to ensure that the parts can be located when needed. If Zone construction is used in conjunction with NC cutting then the build strategy can be used as an organizational framework.

I" its simplest form, computer lofting is accomplished in the same way as manual lofting. The same techniques and methods used by traditional loftsmen can be practiced on the computer. from development of shell plate to expansion of a cambered deck. The greatest power of computer lofting lies, however. in its ability to integrate a number of shipyard disciplines from structural design to steel fabrication to materials handling. The people producing the computer information must work effectively with the steel shop to create a producible design. Coordination is imperative for this technology to succeed.

ZONE OUTFITTING

The National Ship Research Program has identified several levels of shipbuilding technology (Ref. 4). The first is the traditional method described in the introduction above. The second is

Pre-outfitting, where blocks of the vessel are outfitted independently before final assembly but, the outfitting procees is still developed from traditional functional detail design drawings. The third level is zone outfitting where vessel construction involves rethinking the building process as a series of interim products oriented around location in the vessel end/or skills required to produce the product. It is this level that we suggest smell yards should be aiming for.

For most smell yards, some steps towards zone outfitting can be found. A typical example is the separate construction of en aluminum deckhouse which is then attached to the hull (Fig. 7). The key is that aluminum work requires different skills then steel fabrication since the deckhouse is geographically distinct, the separate fabrication is logical. The deckhouse is treated es a separate interim product end could easily be produced by a subcontractor entirely removed from the yard. This interim product is smell enough to be built in a covered shed end lifted by cranes.

Structural elements are traditionally the first area where zone construction logic occurs. unfortunately, the zone logic proceeds no futher. Smell yards Will assemble structural blocks into the hull end only then begin outfitting, yet outfitting productivity benefits tremendously from a zone approach Why not outfit the deckhouse, its requirement for carpentry, extensive electrical work end ventilation, before lifting it into place on the hull7 Physical obstacles such as limited crane capacity can be overcome; it is the mental shift to a new way of approaching vessel construction that is the reel obstacle. Properly applied, the concept of zone outfit must pervade the entire process of constructing a vessel.

The usual construction process cannot accommodate this thinking. Let us outline the "normal" process:

1) Bid on a contract design - Few smell yards have in-house design teams so they must bid on vessel work, either new construction or modifications, that have been designed by either the vessel owner or a third-party. Seldom is that contract design oriented around en explicit construction strategy.

2) Negotiate Contract with Owner - After a successful bid opening the yard will usually settle details of progress payments, schedule, end the design. At this stage, a yard may or may not propose some design or

Figure 7
Deckhouse for en 85 ft. Fireboat

equipment changes to improve productivity or meterial delivery.

3) Prepare Working Drawings by System - Usually the yard will prepare some working drawings to route systems end provide material takeoff. Some times this stage is ommitted entirely on smell vessels in the belief that additional engineering is en unnecessary extra cost. Where drawings are done they are grouped by function i.e., bilge end ballast system arrangement end details.

4) order Materials - During the bid phase the yard estimator will usually contact vendors of specified equipment for price quotes. Following a contract signing, orders will be placed for long lead items while the working drawings are being prepared. Short lead items will be ordered from a materials take off on the working drawings.

5) Phase Progress Payments - The yard will expect partial payment upon achieving construction milestones. A typical schedule might be es follows:

signing contract	20%
laying keel	10%
hull completion	10%
lending main engines	10%
lending deckhouse	10%
launch	10%
engine startup	10%
se* trials	10%
delivery	10%

This type of payment schedule is wrapped around level 1 construction end might result in a builder lending the main engines when the hull is only partially complete in order to get a payment.

6) Brace for omissions, Changes, end Delays - Since outfit is accomplished system by system, a competition for territory ensues, with resulting in-

terference end consequent rework. Should materials ordering have overlooked a pert, the omission will not be discovered until the system is near completion, bringing a scramble to correct the situation.

The above narrative is not intended to imply that smell yards turn out shoddy goods. On the contrary, smell U.S. shipyards can perform the highest quality work in the world with exquisite craftsmanship. We contend that zone outfitting can maintain or improve quality while increasing productivity. The new approach would be es follows:

1) Negotiate Build Strategy into Contract - Since the build strategy is the foundation upon which productivity is based, it should become an' integral part of the contract negotiations. By being up front about construction approach the yard end owner can agree to schedules, drawing reviews, end materials approval formats. The yard can push for minor changes in the design documents that will enhance producibility et no cost in quality.

2) Design end Schedule by Zone - using the contract drawings end the build strategy the vessel is divided up into a sequence of smaller pieces that can be treated as interim products. A logical assembly sequence is then used to create a detailed schedule, integrating materials ordering, drawing production, end fabrication milestones.

3) Phase progress payments to detailed schedule - As pert of the contract negotiations, the payments can be tied to project milestones that are based upon a logical build strategy. The detailed schedule shows when money is needed for materials purchases end manpower. The vessel owner can accurately track yard progress, giving assurance that payments are being properly applied, while the yard can structure a more even cash flow.

4) Brace fur Material Delays - Vendor supplied equipment can still be delayed, regardless of approach. but zone outfitting results in more accurate materials lists, end omissions or delays are caught sooner. By breaking the project into smaller separate pieces, the critical path becomes clearly defined and scheduling impacts can be accurately determined when material delays are encountered.

The benefits of zone outfitting have been alluded to above but deserve repeating. By breaking the project into smeller units the work can be performed indoors with good lighting end reedy hoist assistance. The work can be positioned to maximize downhand work end staging is minimized. Safety is improved which has insurance benefits end improves morale. Less rework is required which saves time end dollars. Additional engineering is required, es much es double, but added engineering cost is more then offset by decreased labor cost resulting in improved productivity (Ref. 5).

So much for generalization. We will now present some portions of zone outfitting that are applicable to smell yards end the vessels they encounter. The three portions are on-unit assembly. on-block assembly. and standards.

Cm-unit assembly

We will define a unit as a collection of piping, equipment, wiring, end assorted structure grouped by common geography end/or function. One example would be to group bilge/ballast/fire pumps together with their associated manifolds, strainers. end motor controllers. Structural elements can function es pipe hangers or grating supports while also providing sufficient rigidity to allow the unit to be moved.

Design of such a "nit must account for access during assembly, weight end attachment points for lifting, end eccess for installation on-board. All wiring end most painting should be completed before the unit leaves the assembly area.

The similarity between units end purchased pieces of equipment should be stressed. A steering gear hydraulic set, bathroom module (Fig. 8), or a generator can all be viewed es units for zone outfitting. In fact a yard may choose to treat custom units like purchased vendor equipment end have a subcontractor assemble them.

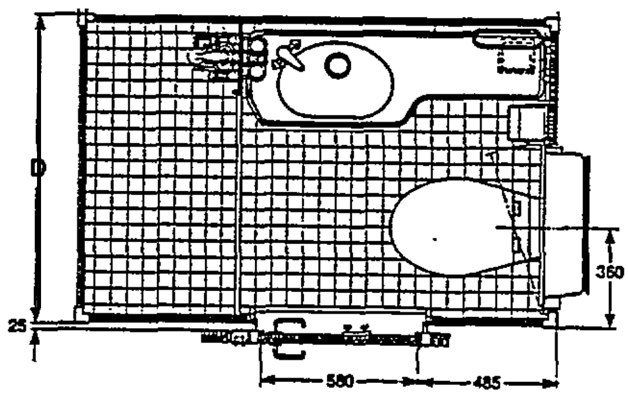

Figure 8
Modular Bathroom Assembly

On-block Assembly

A block is a major subdivision of the project consisting of structure and associated outfit. The block size is chosen on crane capacity and/or assembly logic. A typical example would be a lazarette section of a tug complete with steering gear hydraulics, motor controllers, rudder tube, lighting, and bilge piping. By careful selection of the erection seam, this block might be constructed separately without interferring with the shafting. Fig. 9 shows some partial outfitting of a block where large firemain piping is installed in the overhead of an fireboat engineroom before turning the block over.

Problems with block interconnections have been discussed in Ref. 6 but a few words appropriate to small yards are warranted. Many vendors offer fittings that are suitable to final connection of blocks, allowing for flexibile joints or misalignment. The "se of poured-resin chocks provides alignment margins for final machinery set-up. Judicious "se Of junction boxes or splices permit wiring to be installed in the blocks. reducing the time consuming job of cable pulling.

Standards

As stated in Ref. 7. 'A standard is an agreed upon published description of an item and/or proceedure defining characteristics between specified tolerances. It normally represents a tried and approved method of doing something . .. Widely used overseas, shipyard standards are a neglected productivity tool in small yards. some yards have adopted steel and pipe fabrication standards for details but the use should be expanded to include outfit details and preferred vendor items. As mentioned in Ref. 6, a large yard could have over 4,000 standards. Their "se benefits all departments of a shipyard from purchasing to design to the shop floor. using

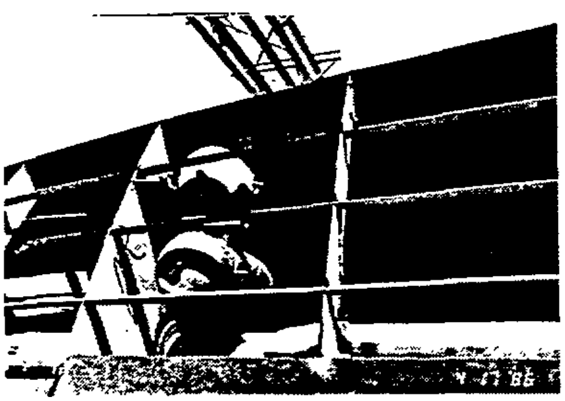

Figure 9
Partial Pre-outfitting

standards, like those shown in Figs. 10 11, provides foe instant recognition of hours, cost, and connection sizes.

Standards should be see" as a quality tool, not just as a means of saving some dollars. In fact, the standards themselves have to represent good quality if they are to receive ready acceptance from the vessel owner and classification agencies. When a yard proposes a line of pumps that they have chosen as their standard, it must be presented as a savings in design and planning and not as a lower cost or cheaper type, even if it is. Adoption of existing standards such as ANSI, Mil-spec or MARAD is encouraged. Such standards present acceptable levels of quality that provide assurance to owner and yard alike.

Zone Outfitting, or Level 3 technology can be adopted by small yards profitably if the experience of larger firms is any guide (Ref. 8). The thoughts sketched above are a few, and not necessarily the best, ideas on the application Of zone outfitting logic.

CONCLUSIONS & REC0MMENDATIONS

The U.S. marine industry has declined steadily in number of vessels, total tonnage Of vessels, number of shipyards and labor force ever since the Second World War. The early part of this decade has been particulary tough on vessel types constructed by smaller yards. However, the march of progress has produced methods by which both small and large yards can improve their productivity and accuracy. The ideas presented in this paper have been selected by the Authors as ones that small yards might implement at modest cost. The expected benefits are summarized as follows:

1) Less labor hours expended.

2) An accelerated construction schedule

3) Safer working conditions

4) A more accurate, higher quality product.

Modest dollar cost has been emphasized throughout. Small yards cannot afford heavy capital investments in crane capacity, automated welding equipment, or expensive mainframe computer systems. All change however brings some cost; adopting the ideas in this paper will be no different. The cost will be in changing thought processes and work habits which means changing people. By judicious subcontracting of work, cross-training of staff, and introduction of the micro-computer as a tool, the small

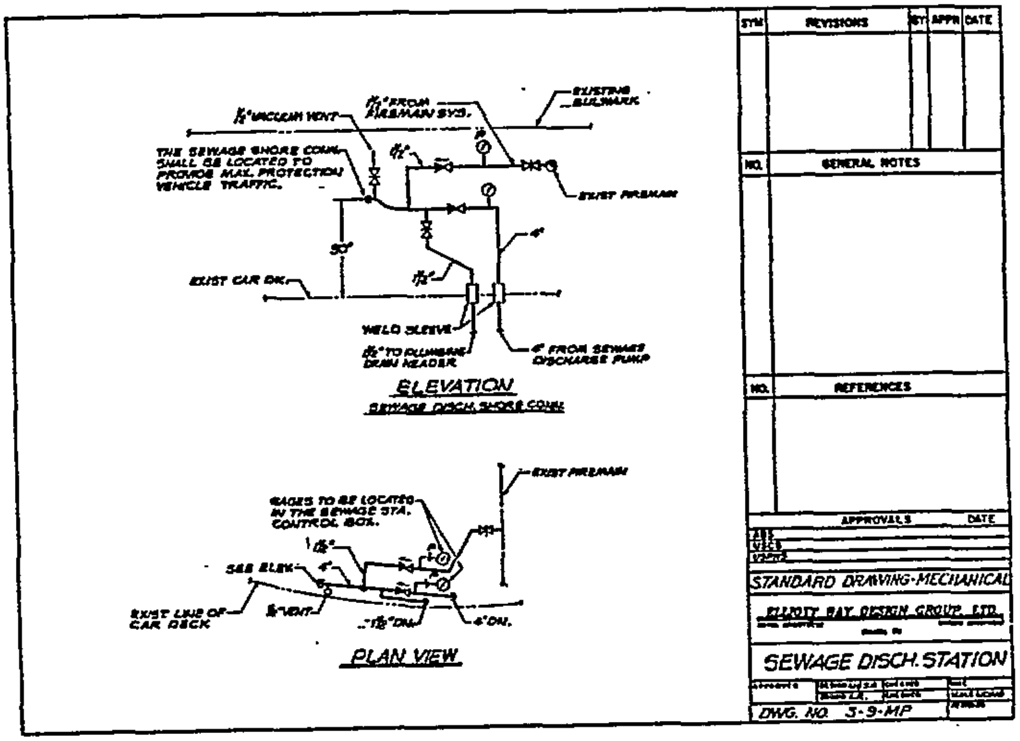

Figure 10
Standard Piping Detail Drawing

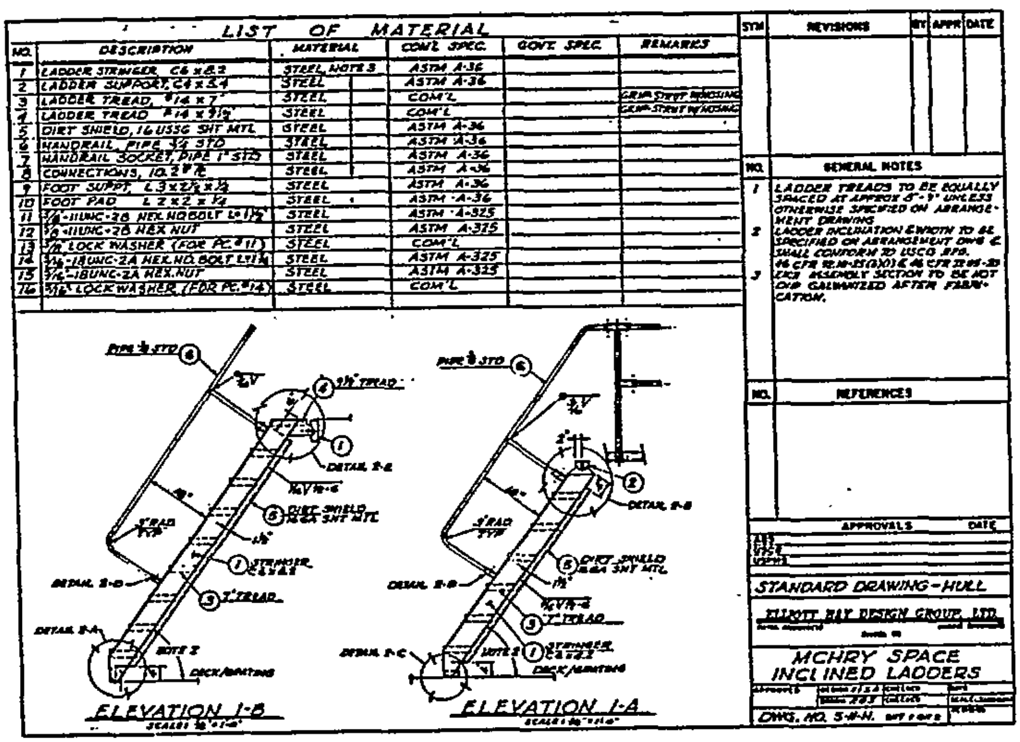

Figure 11
Standard Outfit Detail Drawing

yard can convince its staff that new ideas don’t threaten the traditional skills of the shipbuilder, they build upon them.

As this paper was being researched, the lack of information on or for small yards became very evident. Published information on ship production has focussed on large yards, first on those performing new construction, and, as that dried up, on those overhauling naval vessels. It is time to address the special needs of small yards. The fact that small yards are a vital segment of shipbuilding is one that bears repeating, yet no one seems to have a clear vision of their abilities.

With that in mind, the Authors propose that a technological survey of small yards be undertaken with a scope similar to Ref. 9. Such a survey will reveal much about the ability of small yards to support the needs of the U.S. marine industry and ensure that old skills are polished by contact with new methods.

ACKNOWLEDGEMENTS

The Authors would like to acknowledge with thanks the support of Mr. L.D. Chirillo, Marco shipyard, Seattle, and J.M. Martinac Shipbuilding Corp., Tacoma.

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